Extending IP Flow-Based Network Monitoring with Location Information

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Abstract

IP Flow-based monitoring lacks a mechanism to associate measured IP Flow information with the geographic location of the device where the IP Flows have been observed. This document defines a set of guidelines and best practices to extend IP Flow monitoring protocols with location information of the device (both fixed and mobile) that acts as an IP Flow metering process.

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1. Introduction

The importance of geographic location information on the Internet is growing rapidly. It can be used for business advertisements, admission control and security analysis, for example. Most mobile devices, such as smart phones, tablets and sensors, have capabilities for determining and exposing their geographic location. Besides that, they are accountable for an increasing share of the overall network traffic. In contrast to fixed devices, which usually have their physical location configured in a static manner, mobile devices can exploit several location systems for obtaining their location. This type of information is already used by a wide range of applications and services, such as navigation systems and friend finder services. Relating the location information of a device to this network traffic can be beneficial to many network management and measurement applications, including traffic profiling, anomaly detection and provider-independent network measurements. Hence, exporting location information associated to traffic Flows is desirable in various situations.

Several IP Flow-based monitoring protocols such as the IPFIX protocol [RFC7011] have been designed for the purpose of exporting IP traffic Flows based on Information Elements. This document defines a set of guidelines that provide a means for Metering Processes to encapsulate location information within exported Flows. This will be done by relying on existing location information formats, as they have been developed in other standardization areas for encoding civic locations, geographic coordinates, etc. Several examples including the required set of Information Elements and templates for the IPFIX protocol are given that are suitable for encapsulating pre-existing location information data.

1.1. Motivation

A typical IP Flow Metering Process is used for aggregating IP traffic and related measurement data into Flow Records at a fixed Observation Point. After expiration, Flow Records are sent to a Flow Collector for storage and analysis. The collected information is typically represented in a purely time-based manner, which means that Flow Records provide an aggregated view on network traffic over time. However, when Metering Processes are running on devices with a (frequently) changing physical location, data analysis applications may need to be aware of these movements since they are likely to affect the behavior of the network in terms of routing, throughput, etc. An example scenario is a virtualized environment, where virtual machines change location during migration from one server to another, or even between data centers. Thus, a location-aware metering process will be able to associate their Flows to their current locations.

In fact, we are not dealing anymore with Flows associated to a fixed Observation Point, but with a multitude of sub-Flows for which the Observation Point locations have to be reported. To facilitate this, location information needs to be obtained and processed by the Metering Process in an IP Flow Exporter. In the end, it will be beneficial when network management applications are able to relate service quality parameters to location changes, instead of assuming a single location for all observed parameters.

1.2. Terminology

This document relies on on the definitions of IP The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in [RFC2119].

2. Relationships with IPFIX and GEOPRIV

The IPFIX protocol [RFC7011] and its information model [RFC7012] are the IETF standards for IP Flow-based network monitoring, developed by the IPFIX working group to transfer IP flow data from exporters to collectors. In this document, we rely on the IPFIX terminology and its information model to illustrate how to export location information of a Metering Process to Collecting Process. Within the IPFIX architecture as defined in [RFC5470], in this document we are providing guidelines for developers to extend Metering Processes with capabilities to include location information in data records to be passed to an Exporting Process before being sent to a Collecting Process.

Associating geographic location information with network traffic on the Internet has been addressed by the GEOPRIV working group. There, a Dynamic Host Configuration Protocol (DHCPv4 and DHCPv6) option containing civic address information has been specified in [RFC4776]. A similar option for geospatial information has been defined in [RFC6225]. The group has also defined a set of requirements to be respected when collecting and using Location Objects related to a specific user [RFC3693]. These requirements include usage policies and privacy preferences associated to the Location Object as expressed by a user. All the security and privacy requirements defined in [RFC3693] concern location data collection, and usage MAY be applied to the IPFIX protocol when conveying location information. The GEOPRIV working group has extended the XML-based Presence Information Data Format in [RFC5491], to allow the encapsulation of location information within a presence document.

3. Location Information specifications

The location of a device can generally be defined in two ways, namely by geospatial location coordinates and civic location information. Geospatial location coordinates are made up of latitude, longitude and altitude coordinates, while civic location information encompasses abstract notions of a location, such as "in the kitchen", "in Bakerstreet" or "in a train approaching Nancy, France". The usage of these two types of location representations are addressed by the GEOPRIV group in [RFC5491] and [RFC5139], respectively. This document assumes that devices use one or more existing mechanisms for the purpose of retrieving location information and therefore does not define any new mechanisms for location retrieval.

3.1. Geospatial Location Information

To obtain geospatial location information, one needs to rely on a numeric coordinate system. Such systems provide location information either in two dimensions (latitude and longitude) or three dimensions (latitude, longitude and altitude). Relying on a single point of location is normally not considered sufficient, since an area or volume of uncertainty SHALL be specified. In theory, this area or volume represents a coverage in which the device has a high probability of being found, and the point is the centroid for the area or volume. In [GeoShape] a set of geometric areas and volumes has been specified to define a location with uncertainty. A standard set of Coordinate Reference Systems (CRS) and units of measure are also specified in [GeoShape]. Implementations MUST specify distances and heights in meters as defined in EPSG 9001. Angular measures MUST be specified using degrees as identified by the EPSG 9102 code. The values of EPSG codes can be resolved by using the CRS Registry Service operated by the Oil and Gas Producers Association [OGP].

3.2. Civic Location Information

In contrast to geospatial location information, which relies on numeric data formats, the civic location format conveys pure textual information. It is applicable to device locations in buildings, for example. It MAY be a civic address closely related to a postal address, commonly used by local postal services for delivering mail. It MAY also be some approximated information, such as "living room", "Office 123 in Building 2". The civic location information format has been addressed in [RFC4776], where a set of parameters are provided to describe civic locations. In contrast to geospatial location information, which is the geospatial location of the device as a set of latitude, longitude and altitude coordinates represented by a CRS, civic location information can often be interpreted even if incomplete. For example, while geospatial information is not

available inside buildings, civic location information can still provide an estimation of a device's location.

4. Extending Metering Processes with Location Information

This section specifies how to carry the location information of the device acting as an IPFIX Flow Exporter from the Metering Process to the Collecting Process, to associate the IP Flow information with the location where the flows are measured. The provided specifications SHALL be used by developers to extend a Metering Process for constructing and sending template and data records including location information to a Collecting Process.

4.1 Applicability

Extending Metering Processes to include location information in data records with respect to a certain template is applicable to cases where management applications require knowing the location of the device acting as an IPFIX Flow Exporter. A typical example is a mobile device changing its location while exporting IP Flow records. This method requires that the Metering Process is able to obtain location information of the device using one or several localization methods (GPS, Network, Cell, DHPCP, etc.), as defined in section 6.

Associating location information with measured IP Flow information is an interesting feature for several network management applications (e.g., accounting, traffic profiling, traffic engineering, QoS monitoring, attack/intrusion detection) as specified in [RFC3917]. Location data records provide space dimension to these applications, in addition to the traditional time and volume dimensions provided by IP Flow measurements. Currently, usage-based accounting for IP services relies on time or volume. Besides that, accounting can be performed per location when enabling location information in Metering Processes. For the case of traffic profiling, providing the location of traffic measurements is useful for network planning, dimensioning activities and traffic engineering methods, for example. Typically, the traffic distribution is characterized by using parameters of flows in a specific location. Associating Flow information with their measurement geographic locations will also enable security applications to detect anomalous activities. In the case of mobile devices, the characterization of communication patterns using only time and volume is not enough to detect unusual location-related communication patterns. For example, a mobile device has a specific communication pattern at each location and when the location changes the communication pattern changes also. If the device is attacked the communication pattern in respect with the device location is unusual that will be easily detected by the security monitoring application. However, this unusual communication pattern over space becomes usual

over time since it has been observed before. QoS monitoring applications will also benefit from the presence of location information with the Metering Process since it will allow for correlating quality parameters of IP Flows with respect to their measurement location. Thus, fine-grained QoS parameters can be validated and analyzed. For example, the application will be able to correlate IP Flow, their delays and their locations.

4.2 Enabling Location Extensions

Before enabling location extensions in Data records, the Metering Process SHOULD check if a localization method that provides location information is available on the device. The available location information MUST describe a discrete location defined as a place, point or area in which a Metering Process (i.e., IPFIX Flow Exporter) can be found. In situations where a discrete location can be described in multiple ways, each location SHOULD be described by means of a separate Template following the terminology specified in [RFC7012]. A compound Template containing a subTemplateMultiList field as specified in [RFC6313] SHOULD be used in which each top-level element corresponds to a different location Template. For example, the location of a device being at the fifth floor of a particular building can be described using both a geospatial point (the geographic location of the building) and civic information (fifth floor of a building). Exporting more than one location in a Flow Record MUST only be done if the different location descriptions refer to different places. Each time a different type of location data is available to the Metering Process and needed to be sent, the Flow Exporter MUST send the template of the new location format to the Collecting Process.

When several localization methods are available on the device, the Metering Process SHALL select one or several among them. If the available methods provide the same type of location information, it selects only a single method. The selected method is the one with the highest accuracy. According to the accuracy of the method, the Metering Process MUST use the appropriate template and the Information Elements from the set of recommended templates and Information Elements specified in Appendixes A and B. We have to note that other criteria MAY be used to select the localization method. For example, in a mobile device where saving energy is important (due to power constraints, for example), the Metering Process MAY select the less power-consuming method. Specifically, a network-based method is typically less power-consuming than a GPS-based localization method. Configuration options MAY also be available on the Metering Process to configure the location method to be used according to the requirements of the management application.

When one or several localization methods are selected and activated, the Metering process is able to include location information in data records. When an IP Flow is observed by the Metering Process, location information is derived and included in a data record using an appropriate template that SHOULD be sent to the Collecting Process before sending the location data records. The Metering process should be configured to associate a single or multiple location information to each observed IP Flow.

A single location information is derived by the Metering Process either at the time of the first observed packet of the IP Flow or at the time of the last observed packet of the IP Flow. Then, a location data record containing a single location information is built and passed to the Exporting Process. Multiple location information are derived by the Metering Process during the time interval of the observation of the IP Flow. The multiple location information MAY be derived at different time scales. Metering Processes MAY associate two location information, one at the starting time of the observed Flow and the second at the ending time of the Flow. It MAY also sample several information location to be associated with the observed IP Flow.

4.3 Flow expiration Management

With the current IPFIX specifications, the Metering Process expires active Flows under several conditions as described in Section 5.1.1 of [RFC5470]. When the Metering Process enables location information to be associated to observed IP flows and according to the management application requirements, it MAY consider location or distance information for determining whether a flow has to be expired. For example, a Metering Process MAY expire Flows when the device changes its location. For long-running Flows, the Metering Process may use a distance-based expiration policy, such as expiring a Flow upon a configured distance value in meters. In case location information becomes unavailable on the device, the Metering Process SHOULD expire all running Flows to be able to resend the set of templates as described in Section 4.4.

4.4 The Collecting Process's Side

As specified in [RFC5101], the Exporting Process SHOULD transmit the required set of templates specific to location information in advance to the Collecting Process, before sending any data records including location data. When the Metering Process is not able to access a localization method or no method is available to obtain such information, it MUST stop resending to the Collection Process location related templates.

5. Security and Privacy Considerations

This document proposes a set of Information Elements and guidelines for exporting location information using IPFIX. We recognize the privacy sensitivity of exporting such information and advocate the use of measures to protect individual's privacy. Several documents have addressed security and privacy in the context of the Internet in general and IPFIX in particular. First, the use of location information has been discussed in "GeoPriv Requirements" [RFC3693], while threats facing protocols that carry location information are detailed in [RFC3694]. Second, when carrying location information in IPFIX Information Elements, all Messages exchanged between Exporting and Collecting Processes SHOULD be signed and encrypted using Transport Layer Security (TLS) or Datagram Transport Layer Security (DTLS) protocols, as specified in [RFC7011]. Another approach is the use of a secure, underlying communication channel for transporting IPFIX Messages in case the aforementioned transports are unavailable. Third, support for Flow Record anonymization, as expressed in [RFC6235], is strongly recommended, since the dissemination of Flow Records including location information raises greater privacy issues than the dissemination of regular Flow Records.

Preserving the privacy of users SHOULD be addressed by applications using collected monitoring data. We note that collecting and exporting location information associated with information that is able to identify individual by means of their IP addresses, may be illegal or require special clearance in certain jurisdictions.

6. IANA Considerations

This document specifies several new IPFIX Information Elements and types that need to be registered with IANA. The values of existing location methods are enumerated within an IANA registry [RFC4119]. However, integer identifiers for these methods need to be registered with IANA as described below.

Number	Method	Description
0	GPS	Global Positioning System
1	A-GPS	GPS with assistance
2	Manual	Entered manually by a user
3	DHCP	Provided by DHCP [RFC5985]
4	Triangulation	Triangulated from time-of-arrival, signal strength or similar measurement
5	Cell	Location of the cellular radio antenna
6	802.11	IEEE 802.11 access point location

Appendix A. IPFIX Location Information Elements

This appendix contains a set of IPFIX Information Elements that can be used for exporting location-related information of a Metering Process. They SHALL be used for exporting geospatial and civic location, together with IPFIX Information Elements already defined in [RFC7012] for exporting IP traffic Flows.

A.1. geospatialLocationCRSCode

Description: Denotes the Coordinate Reference System (CRS) codes according to which the location coordinates are organized and related to the real world, as specified in [GEOSHAPE]. In this document we mandate the use of the World Geodetic System 1984 (WGS84) [WGS84] coordinate reference system and the usage of the European petroleum survey group (EPSG) code 4326 for two-dimensional (2D) shape representations and EPSG 4979 for three-dimensional (3D) volume representations.

Data Type: unsigned16
Data Type Semantics: identifier
PEN (provisional): 12559 (Inria)
ElementId: 401

A.2. geospatialLocationLat

Description: Denotes the coordinate information value of the latitude.

Data Type: float64
PEN (provisional): 12559 (Inria)
ElementId (provisional): 402

A.3. geospatialLocationLng

Description: Denotes the coordinate information value of the longitude.

Data Type: float64
PEN (provisional): 12559 (Inria)
ElementId (provisional): 403

A.4. geospatialLocationAlt

Description: Denotes the coordinate information value of the altitude.

Data Type: float64
PEN (provisional): 12559 (Inria)
ElementId (provisional): 404

A.5. geospatialLocationRadius

Description: Denotes a radius value (in meters) of a location described using a circular area in a two-dimensional CRS or a sphere shape in a three-dimensional CRS.

Data Type: float32
Data Type Semantics: quantity
PEN (provisional): 12559 (Inria)
ElementId (provisional): 405

A.6. civicLocationType

Description: Denotes the civic location information type as specified in [RFC4776].

Data Type: unsigned8
PEN (provisional): 12559 (Inria)
ElementId (provisional): 406

A.7. civicLocationValue

Description: Denotes a civic location information element that MUST be encoded as a UTF-8 string. The location information MAY be a civic address as specified in [RFC4776] or information on proximity to known objects.

Data Type: string
PEN (provisional): 12559 (Inria)
ElementId (provisional): 407

A.8. locationMethod

Description: Denotes the way in which the location information has been obtained. The locationMethod sub-registry is defined in Section 8.1.

Data Type: unsigned8
Data Type Semantics: identifier
PEN (provisional): 12559 (Inria)
ElementId (provisional): 408

A.9. locationTime

Description: Denotes the time when the location information is obtained on a device acting as an IPFIX Flow Exporter. The time is expressed in seconds since January 1, 1970, 00:00:00 UTC.

Data Type: dateTimeSeconds
Data Type Semantics: quantity
PEN (provisional): 12559 (Inria)
ElementId (provisional): 409

A.10. deviceId

Description: Denotes an identifier of a physical device acting as an IPFIX Flow Exporter. The Exporting Process uses this identifier to uniquely identify the device where Flows were metered. The identifier is unique per device. This Information Element can be used when an IPFIX Flow Exporter is behind a NAT.

Data Type: unsigned64
Data Type Semantics: identifier
PEN (provisional): 12559 (Inria)
ElementId (provisional): 410

Appendix B. Recommended IPFIX Templates for Location Export

This appendix contains a set of recommended IPFIX Templates for exporting geospatial and civic location information. The geospatial templates are related to a point, circle or area shapes. The definition and usage of the shapes is covered in [GeoSHAPE]. Civic locations can be exported using a Template containing a subTemplateList [RFC6313], where each element of the list corresponds to a Template.

B.1. Geospatial Point Location Template

The point shape is the simplest form of a geospatial location, which SHOULD be used when there is no known uncertainty. The following Template is defined for exporting a 2D geospatial point location:

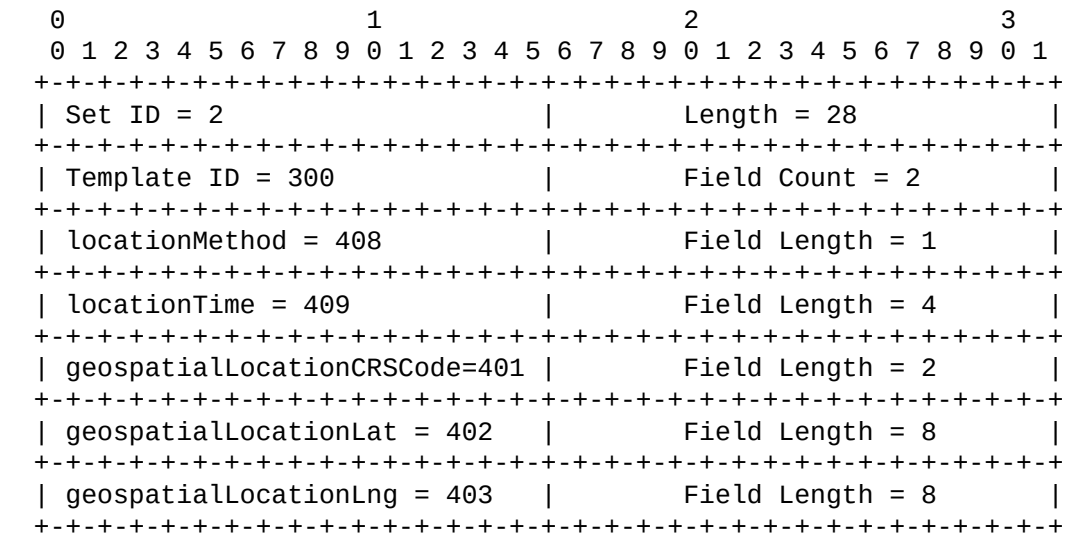


Figure 1: Template for exporting a 2D point-based geospatial location

For illustration, the following presents an example Data Record to export a 2D geospatial point location:

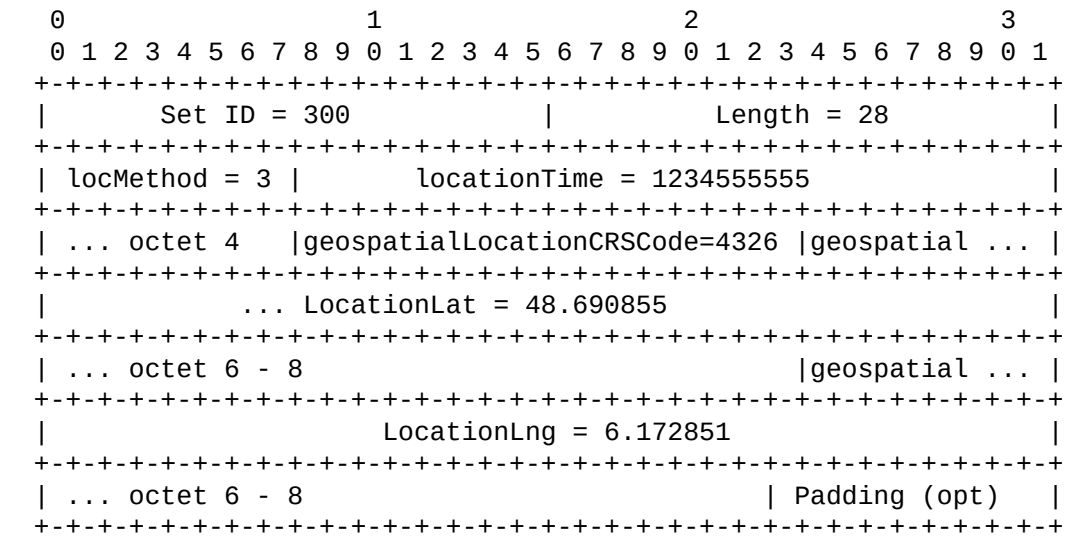


Figure 2: Data Record of a geospatial 2D point location

B.2. Geospatial Circle Location Template

The circle Template is suitable for exporting the location of a flow observed within a circle shape where its center is represented using a geospatial point position and its radius represents the uncertainty.

```
Template Record for Geospatial Circle (ID = 301)
 | locationMethod(408)[1]
 | locationTime(409)[4]
 | geospatialLocationCRSCode(401)[2]
 | geospatialLocationRadius(405)[4]
 | geospatialLocationLat(402)[8]
 | geospatialLocationLng(403)[8]
```

Figure 3: Template for exporting a circle-based geospatial location

The following presents an example of a Data Record carrying a circle-based geospatial location:

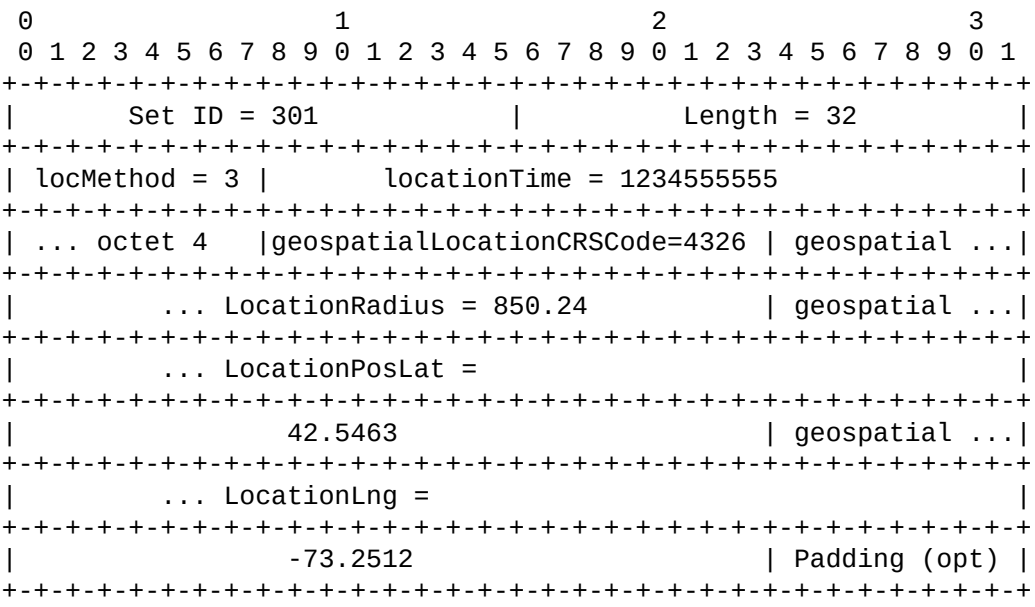


Figure 4: Data Record of a circle-based geospatial location

B.3. Geospatial List Template

The list locations Template is suitable for exporting a variable-length list of different geospatial point positions of a single flow. For example, it could be used to export the start and the end locations of a flow. The template relies on a subTemplateList data type to export the list of geospatial point-based positions. This template requires [RFC6313] compliant Exporting and Collecting Processes. Figure 5 depicts an example of such a subTemplate for exporting each element of the list.

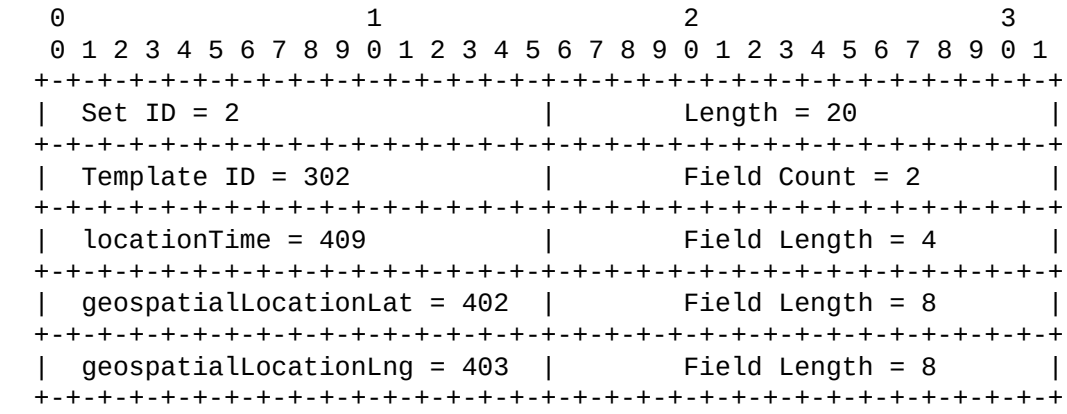
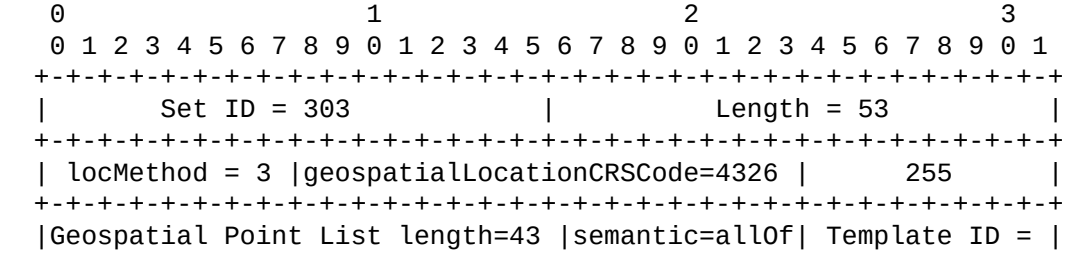


Figure 5: Template for exporting a geospatial 2D point-based position

Template Record for Geospatial List (ID = 303)
 | locationMethod(408)[1]
 | geospatialLocationCRSCode(401)[2]
 +-subTemplateList(292)[0XFFFF]
   +-Geospatial 2D Point position Template Record(302)[16]

Figure 6: Template for exporting a geospatial list of locations

The following presents an example Data Record carrying a list of two geospatial point positions. Each point-based position is defined as an element of a subTemplateList Information Element with semantic "allOf".



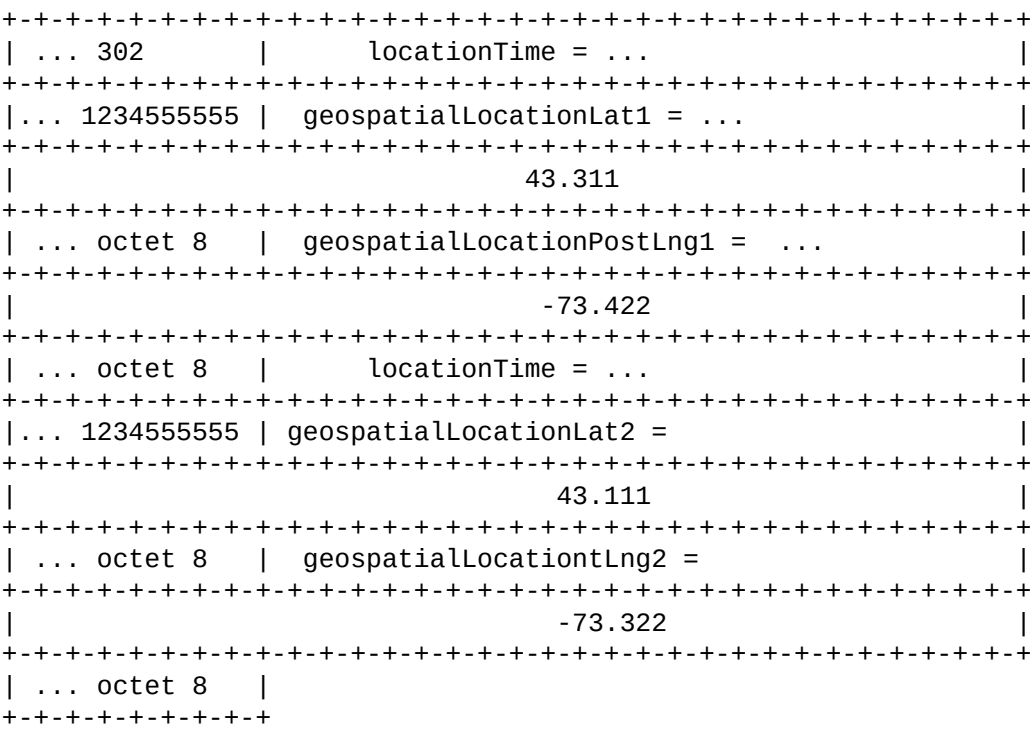


Figure 7: Data Record of a geospatial list of point-based locations

B.4. Civic Location Template

A civic-based location Data Record consists of a tuple of (civicLocationType, civicLocationValue) Information Elements. Each tuple is defined as an element of a subTemplateList Information Element with semantic "allOf". This template requires [RFC6313] compliant Exporting and Collecting Processes.

Template Record for Civic location (ID = 304)
 | locationMethod(408)[1]
 | locationTime(409)[4]
 +-subTemplateList (292)[0xFFFF]
   +-Civic element Template Record (ID = 305)
     | civiLocationType(406)[1]
     | civicLocationValue(407)[v]

Figure 8: Template for exporting a civic location

The "Civic element" Template Record, as shown in Figure 8, MUST be defined for each tuple. For the purpose of illustration, we consider

exporting the civic location "Inria Nancy-Grand Est, Building B, Office 123" obtained through DHCP. Using the Template described in Figure 8, the resulting Data Record is as follows:

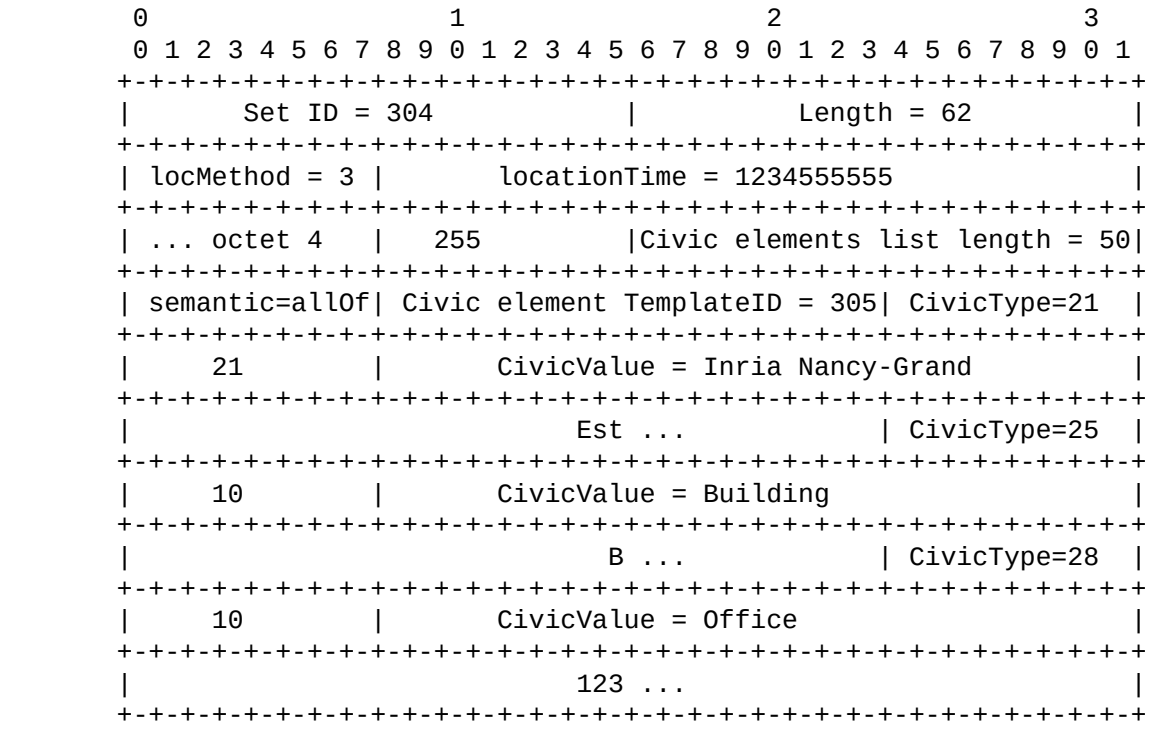


Figure 9: Data Record of a civic location

Note that the values of the civiLocationType are defined in [RFC4776].

B.5. Compound Location Template

A compound location is used to describe a location, represented by a composite of both civic and geospatial information. An example situation is a two-dimensional geospatial 2D point position (latitude, longitude) describing a location of a building, and a civic element representing the floor in that building. A subTemplateMultiList [RFC6313] SHOULD be used to export a Template for both geospatial and civic information. To represent the above example, the following Template is defined:

Template Record for Compound Location (ID = 306)
 | locationTime(409)[4]
 +-subTemplateMultiList(293)[0XFFFF]
   +-Geospatial Template Record (ID = 307)

```
      | locationMethod(408)[1]
      | geospatialLocationCRSCode(401)[2]
      | geospatialLocationLat(402)[8]
      | geospatialLocationLng(403)[8]
    +-Civic location Template Record (ID = 308)
      | locationMethod(408)[1]
      | civicLocationType(406)[1]
      | civicLocationValue(407)[v]
```

Figure 10: Template for exporting a compound location

A data Record encoded using the Template shown in Figure 11 is represented as follows:

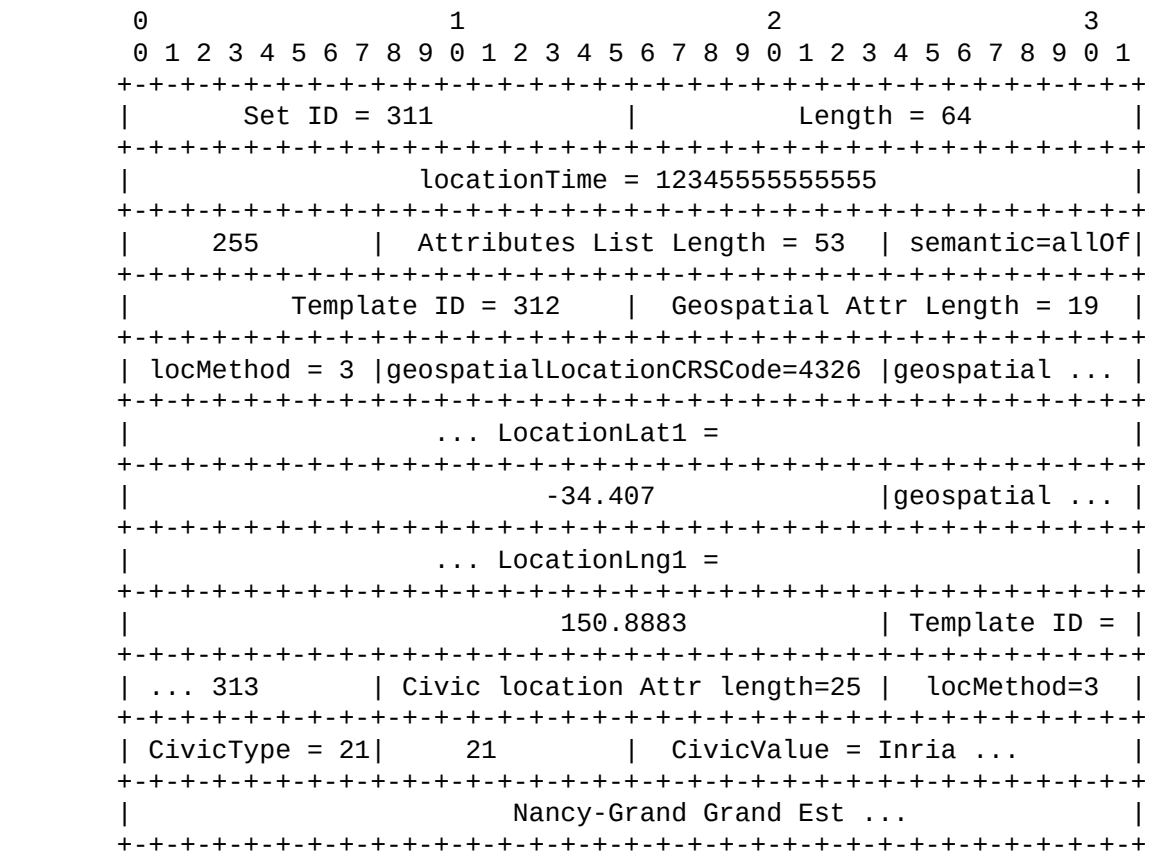


Figure 11: Data Record of a compound location

Appendix C. Example Implementation

This appendix shows an example application that relies on the set of IPFIX Information Elements described in Appendix A. This application, named SURFmap, is a network monitoring tool based on the Google Maps API that uses Flow data to visualize network Flows on a map [SURFMAP]. By default, geolocation databases are used for retrieving the (estimated) physical location associated to an IP address. The Information Elements described in this document, however, will allow SURFmap to use the absolute location information exported for Flows.

SURFmap has been developed in the past as a plugin to NfSen [NFSEN]. NfSen provides a Web-frontend to nfdump [NFDUMP], which is a set of tools for flow data collection and processing, among others. To support collection and processing of Flow Records containing any of the new Information Elements (e.g. by SURFmap), an extension to nfdump has been developed.

The following presents a set of Flow Records that have been exported by a mobile Flow Exporter. Several fields, such as destination IP address and port number, location timestamp and location method have been left out for the sake of space. It is clear that the mobile device has moved while exporting Flow Records, as the latitude and longitude coordinates have changed over time.

Start time	Src IP Addr:Port	Pkts	Bytes	Latitude	Longtitude
20:19:21.852	173.194.40.113:443	9	2730	48.690855	6.172851
20:21:42.307	91.202.200.229:80	13	9137	48.690855	6.172851
20:21:42.307	10.21.20.232:59521	15	1547	48.690855	6.172851
20:22:38.084	73.194.40.113:80	8	1799	48.690855	6.172851
20:22:38.084	10.21.20.232:34056	9	877	48.690855	6.172851
21:17:13.498	173.194.45.80:443	12	2830	48.713145	6.17526
21:17:13.498	10.21.20.232:49233	15	2301	48.713145	6.17526
21:17:16.919	10.21.20.232:15572	1	72	48.744506	6.154815
21:17:16.919	172.20.2.39:53	1	257	48.744506	6.15481

Normative References

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